

*BEHAVIORAL MOMENTUM: THE EFFECTS OF
THE TEMPORAL SEPARATION OF
RATES OF REINFORCEMENT*

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In Part 1 of the experiment, rats responded under a variable-interval (VI) 30-s schedule and a VI 120-s schedule, with each in effect for a block of consecutive sessions. That is, the two VI schedules were presented in successive conditions. In Part 2 the VI schedules alternated each day, and in Part 3 the schedules alternated within the session as a multiple schedule. For half of the rats in Parts 1 and 2, the VI schedule alternated every few minutes within the session with a stimulus that signaled extinction. For each part, once response rates had stabilized, resistance to change was measured by prefeeding and extinction. When the schedules were examined in successive conditions (Part 1), resistance to extinction was greater under the VI 120-s schedule of reinforcement than under the VI 30-s schedule, but no consistent differences in resistance to prefeeding were observed between the two VI schedules. When the VI schedules alternated each day (Part 2), resistance to extinction was greater under the VI 120-s schedule. However, no consistent differences in resistance to prefeeding were observed between the VI schedules without extinction in Group A, but resistance to prefeeding was greater under the VI 30-s schedule for rats with the added extinction component in Group B. When the VI schedules alternated within the session as a multiple schedule (Part 3), resistance to extinction and resistance to prefeeding were greater under the VI 30-s schedule. The data suggest that different rates of reinforcement, and their accompanying discriminative stimuli, must be compared within the same session (or at least on alternate days) to produce data consistent with the behavioral momentum model.

Key words: behavioral momentum, resistance to change, extinction, simple schedules, multiple schedules, lever press, rats

Resistance to change is the degree to which operant responding persists when a disrupting operation is introduced. For example, Cohen (1986) trained rats to press a lever under a multiple fixed-interval (FI) 30-s FI 120-s schedule of reinforcement. After responding stabilized, three consecutive extinction sessions were conducted. Under baseline conditions the rate of lever pressing was higher in the FI 30-s component than in the FI 120-s component, and when food was discontinued resistance to extinction was greater in the FI 30-s component. This experiment illustrated two important and independent characteristics of behavior: rate of response and resistance to change. Together, these two

variables make up what Nevin (1974, 1979) termed *behavioral momentum*.

According to the behavioral momentum model, responding has both velocity (response rate) and mass (resistance to change). Research on behavioral momentum has focused on variables that affect responses' persistence during interfering events such as extinction, satiation, the presentation of response-independent food, punishment, conditioned suppression, and alternative sources of response-dependent reinforcement (e.g., Cohen, 1986, 1996; Cohen, Riley, & Weigle, 1993; Lattal, 1989; Mace et al., 1990; Nevin, 1974, 1979, 1988, 1992; Nevin, Tota, Torquato, & Shull, 1990). As illustrated in the multiple FI 30-s FI 120-s schedule (Cohen, 1986), much of this research has demonstrated that there is a direct relationship between rate of reinforcement and resistance to change.

The direct relationship between resistance to change and rate of reinforcement has been demonstrated primarily under procedures in which the different schedules of reinforcement for the performances during baseline occur within the same session—as

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multiple, chained, or concurrent schedules (e.g., Cohen, 1986; Nevin, 1974, 1979, 1988, 1992; Nevin, Mandell, & Yarensky, 1981; Nevin et al., 1990). This relation has not been consistently observed under procedures in which baseline training consists of blocks of sessions, each with a single schedule of reinforcement (e.g., Clark, 1958; Cohen, Furman, Crouse, & Kroner, 1990; Cohen et al., 1993; Hancock & Ayres, 1974). In what here will be called *complex schedules*, more than one schedule of reinforcement operates within an experimental session, either successively or concurrently, and each schedule is correlated with a different discriminative stimulus. In what here will be called *simple schedules*, only one schedule of reinforcement operates within a session, and that schedule is correlated with the entire stimulus context of the experimental chamber. When examining the effects of different rates of reinforcement on resistance to change in simple schedules, those schedules may be arranged by having a single group of subjects exposed to different rates of reinforcement across successive conditions (e.g., Cohen et al., 1990) or by using independent groups of subjects (e.g., Church & Raymond, 1967; Clark, 1958). Some research with simple schedules of reinforcement has demonstrated a direct relationship between rate of reinforcement and resistance to change (e.g., Blackman, 1968; Church & Raymond, 1967; Millenson & de Villiers, 1972), whereas other research has failed to do so (e.g., Ayres, 1968; Clark, 1958; Cohen et al., 1990, 1993; Hancock & Ayres, 1974; Leslie, 1977).

It has been difficult to determine what variables account for the consistent relationship between rate of reinforcement and resistance to change in complex schedules, but not in simple schedules, because the relevant studies differ in many ways. Recently, however, Cohen et al. (1993) compared resistance to change in simple and multiple schedules of reinforcement using similar subjects, apparatus, and procedures. They demonstrated a direct relationship between rate of reinforcement and resistance to change in multiple schedules but not in simple schedules under tests of prefeeding and extinction. Under simple schedules, there was either no consistent relationship between resistance to change and rate of reinforcement or resis-

tance to change was inversely related to rate of reinforcement. Furthermore, Cohen et al. (1993) showed that different relationships under simple and multiple schedules were not a result of differences in the schedule of reinforcement during training (i.e., fixed ratio [FR], variable interval [VI], FI, and variable ratio), the species of subjects (i.e., rats and pigeons), or the type of resistance-to-change test (i.e., prefeeding and extinction). It remained unclear, however, what variables were responsible for the failure to find data consistent with the behavioral momentum model under simple schedules of reinforcement.

There are two reasons why a direct relationship between rate of reinforcement and resistance to change might be observed in multiple schedules but not in simple schedules. First, in multiple schedules each component is associated with a different rate of reinforcement, and these rates alternate frequently within the session. In simple schedules that are arranged across successive conditions (e.g., VI 30 s in Condition 1 and VI 120 s in Condition 2), the two rates of reinforcement are separated by weeks or months. Furthermore, when independent groups of subjects are used, a subject is never exposed to more than one rate of reinforcement. Frequent alternations, and thus temporally close comparisons, of different rates of reinforcement might be necessary to observe a direct relationship between rate of reinforcement and resistance to change.

Second, there is a significant difference in the stimulus-reinforcer relations in multiple and simple schedules. With a multiple schedule, each component schedule is signaled by a different stimulus, and each stimulus is associated with a different rate of reinforcement. With simple schedules, the prevailing stimulus remains the same when reinforcement frequencies are varied across conditions (Cohen et al., 1990, 1993), and, with the exception of the blackout at the beginning and the end of a session, there is no other stimulus that signals a lower or higher rate of reinforcement. Consequently, under multiple schedules the rate of reinforcement in the presence of one stimulus can provide a context that influences the effectiveness of the rate of reinforcement in the other stimulus. In a simple schedule it is unclear what the

context is against which the rate of reinforcement is compared. One possibility is that the stimulus-reinforcer context in the operant chamber is compared against the stimulus-reinforcer context in the home cage.

Regardless of the mechanism that might be responsible for the difference in the relationship between rate of reinforcement and resistance to change under simple and multiple schedules, it is clear that the stimulus-reinforcer relations differ substantially in the two types of schedules. Inasmuch as the behavioral momentum model (Nevin, 1984, 1992; Nevin, Smith, & Roberts, 1987; Nevin et al., 1990) emphasizes the importance of stimulus-reinforcer relations in determining behavioral mass, these differences might account for the different results previously cited (e.g., Cohen et al., 1993).

The present experiment was designed to examine the effects of the temporal separation of rates of reinforcement on resistance to change. Further, it was designed to determine the importance of some of the differences in stimulus-reinforcer relations that exist between simple and multiple schedules. Rats were assigned to either Group A or B, and the rats in each group were studied across Parts 1, 2, and 3 of the experiment. Rats in Group A responded under simple VI 30-s and VI 120-s schedules, and each schedule was associated with a different discriminative stimulus. In Part 1 these rats responded under VI 30-s and VI 120-s schedules, each being in effect for a block of consecutive sessions (successive conditions). In Part 2 the VI 30-s and VI 120-s schedules alternated each day, and in Part 3 the schedules alternated within the session as a multiple schedule. In each part, resistance to change was assessed by prefeeding and extinction. The rats in Group B were treated like those in Group A, except that the current VI schedule alternated within the session with a stimulus that signaled extinction. Technically, one condition was a multiple VI 30-s extinction schedule, and the other was a multiple VI 120-s extinction schedule. For these rats, then, the VI 30-s and VI 120-s schedules were arranged in a context of differential reinforcement so that the stimulus-reinforcer context of the current VI schedule could be compared to another stimulus-reinforcer context (extinction) within the same session, an arrangement

found in multiple schedules. In Parts 1 and 2, the VI 30-s and VI 120-s schedules were temporally separated from each other as in Group A. If no differences in resistance to change were found under the simple VI 30-s and VI 120-s schedules in Group A, but differences were found between the VI 30-s extinction and VI 120-s extinction schedules in Group B (i.e., greater resistance to change in the VI 30-s schedule than in the VI 120-s schedule), then it could be argued that the temporal separation between the VI 30-s and VI 120-s schedules was not responsible for the failure to find data consistent with the momentum model in simple schedules. Conversely, if no differences in resistance to change were found under the VI 30-s and VI 120-s schedules in Groups A and B in Parts 1 and 2, then it would suggest equivalent behavioral mass under VI 30-s and VI 120-s schedules despite conditions of differential reinforcement.

METHOD

Subjects

Eight experimentally naive male Sprague-Dawley albino rats (Camm Research), approximately 7 months old at the start of the experiment, were used. The rats weighed between 245 and 294 g after food deprivation and were maintained at 80% of their free-feeding weights. Water was freely available in their home cages, where a 12:12 hr light/dark cycle was maintained (lights on at 6:00 a.m.).

Apparatus

Eight operant conditioning chambers (Coulbourn Instruments) for rats were housed in sound-attenuating cubicles. Each chamber contained a recessed food cup in the bottom center of the work panel. The response lever was 22 mm from the right wall, 28 mm from the grid floor, and operated with a minimum force of approximately 0.24 N. A 28-V houselight was located above the food cup near the top of the chamber. A Gerbrands or Coulbourn feeder delivered 45-mg Noyes food pellets. White noise was present during the session to mask extraneous sounds. Contingencies were controlled by an IBM-PC computer, Coulbourn Instruments Lab-Linc interface, and Pascal programming.

Procedure

Rats were placed in the chambers overnight and exposed to a continuous reinforcement (CRF) schedule in which a food pellet was delivered every 10 min independently of behavior. The houselight was on during each session. After lever pressing was established, each rat received two 8-hr sessions of CRF, two sessions under a VI 10-s schedule that lasted for 60 reinforcers, two 1-hr sessions under a VI 20-s schedule, and two 1-hr sessions under a VI 30-s schedule. Every VI schedule contained 20 intervals that were derived from the formula of Catania and Reynolds (1968, p. 380). One interval was randomly chosen following each food presentation until the entire set of 20 intervals was exhausted, and then the random selection was repeated. Under the VI schedule the first response after a sampled interval from the distribution turned on the white feeder light for 1 s and delivered a food pellet. The lever was not operative during the 1-s feeder cycle. Sessions were conducted 5 or 6 days per week. Subjects were then randomly assigned to one of two groups (4 in each group): Rats in Group A were exposed to simple VI 30-s and VI 120-s schedules, and for Group B each VI schedule alternated with extinction within the session. Rats in both groups were exposed to the VI 30-s and VI 120-s schedules across successive conditions (Part 1), on alternate days (Part 2), and within the same session (Part 3). Table 1 presents the sequence of conditions and the number of sessions under each condition.

Part 1 (Group A): VI 30-s and VI 120-s schedules in successive conditions. Rats 2 and 11 were trained under a VI 30-s schedule in the presence of the constant houselight. Sessions lasted 72 min, and this condition was maintained until responding appeared visually to be stable (i.e., no increasing or decreasing trends in overall response rates for at least five consecutive sessions).

After responding stabilized, resistance-to-change tests were conducted. First, rats were prefed 2% of their free-feeding body weights in Purina® rat chow in their home cage 1 hr before the session. After baseline response rates and 80% body weights were recovered, rats were prefed 4% of their free-feeding body weights before the session. In the next

Table 1

The number of sessions under each condition before the first resistance-to-change test. In Part 1 the VI 30-s and VI 120-s schedules were conducted in successive conditions. In Part 2 the two schedules alternated each day. In Part 3 the two schedules alternated within the session as a multiple schedule. For Group B the VI schedule alternated with 3 min of extinction within the session.

Group A (without extinction)				Group B (with extinction)			
Rat	Part	VI 30 s	VI 120 s	Rat	Part	VI 30 s	VI 120 s
2	1	57	29	6	1	62	23
	2	41	33		2	27	28
	3	22	22		3	23	23
11	1	55	24	16	1	69	22
	2	28	27		2	31	27
	3	25	25		3	23	23
4	1	47	51	7	1	26	54
	2	31	28		2	30	28
	3	23	23		3	33	33
14	1	28	58	18	1	24	50
	2	43	39		2	30	28
	3	45	45		3	25	25

Note. In Part 1 Rats 2, 11, 6, and 16 had the VI 30-s schedule in the first condition and the VI 120-s schedule in the second condition. The order was reversed for Rats 4, 14, 7, and 18.

two tests the 2% and 4% prefeeding conditions were replicated. Finally, three consecutive extinction sessions were conducted, during which reinforcers were no longer delivered. Successive prefeeding resistance-to-change tests were separated by at least three baseline sessions, and response rate on the session before each test had to be within the range of response rates of the five baseline sessions preceding the first test. At least five baseline sessions were conducted between the last prefeeding test and the extinction test. After the last extinction session, response rates were recovered, and the schedule was changed to VI 120 s. In this condition the stimulus that signaled the VI 120-s schedule was the houselight flashing on for 0.1 s and off for 0.1 s. Responding was maintained in the presence of the flashing houselight until response rates stabilized and the resistance-to-change tests were repeated. Conditions 1 and 2 may be conceptualized as two components of a multiple schedule in which the two schedules (VI 30 s and VI 120 s) and their respective stimuli (constant and flashing houselight) were separated by numerous ses-

sions rather than alternating within the session.

Rats 4 and 14 were treated exactly like Rats 2 and 11, except that Conditions 1 (constant houselight) and 2 (flashing houselight) were VI 120 s and VI 30 s, respectively. Also, Rat 4 was only tested once with 2% and 4% prefeeding under the VI 30-s condition. In this instance, and in other conditions where noted, replications of prefeeding tests were not conducted because the rat took an inordinate number of sessions to stabilize before a resistance-to-change test, and the other rats had proceeded to the next condition.

Part 1 (Group B): VI 30-s extinction and VI 120-s extinction schedules in successive conditions. The rats in Group B were treated like those in Group A, except that the VI 30-s and VI 120-s schedules were each accompanied by 3-min periods of extinction that were signaled by a third stimulus. Rats 6 and 16 responded under a VI 30-s schedule in the presence of a constant houselight, and responding in the presence of a flashing houselight (1 s on and 1 s off) had no scheduled consequences. Thus, Condition 1 was a multiple VI 30-s extinction schedule. Each component of this multiple schedule lasted 3 min and was separated by a 30-s timeout, during which the houselight was turned off and lever presses had no scheduled consequences. Sessions were terminated after each component had occurred 12 times. VI 30-s and extinction components were scheduled in pairs, and one of the two components within each pair was chosen randomly to occur first. When components switched from VI to extinction, any time left over in an interval of the VI schedule was carried over to the next VI component. After overall response rates stabilized in both components of the multiple schedule, resistance-to-change tests were conducted as described for Group A. After the last extinction test, the baseline schedule was reinstated so that response rates could be recovered, and then the schedule was changed to multiple VI 120-s extinction. The VI component was signaled by the houselight flashing on and off every 0.1 s, and the extinction component was signaled by the houselight flashing on and off every 1.0 s. Resistance-to-change tests were repeated after response rates stabilized. Rats 7 and 18 were treated like Rats 6 and 16, except that Conditions 1

and 2 were multiple VI 120-s extinction and multiple VI 30-s extinction, respectively.

Part 2 (Group A): VI 30-s and VI 120-s schedules alternating each day. This condition was a replication of Part 1 for Rats 2, 11, 4, and 14, except that the VI 30-s and VI 120-s schedules alternated each day. When response rates stabilized for either VI schedule, resistance-to-change tests were conducted for that schedule only. Resistance-to-change tests were conducted as previously described. Rats 2 and 14 had only one determination of the 2% and 4% prefeeding tests. Extinction tests were done for one schedule at a time and on alternate days, just as in training. Thus, if extinction was tested in the VI 30-s schedule, then an extinction session alternated daily with a VI 120-s schedule until the three extinction sessions were completed. After the last extinction test, responding was recovered, and extinction was similarly examined in the other schedule. Conducting the extinction tests on only one schedule at a time was done in order to avoid potential carry-over effects of extinction from one schedule to the other. Inasmuch as the two VI schedules were treated independently, a resistance-to-change test was first conducted under the schedule that first met the stability criterion. In the initial determination of the 2% prefeeding test, the first test occurred under the VI 30-s schedule for Rats 4 and 11 and under the VI 120-s schedule for Rats 2 and 14. In the initial determination of the 4% prefeeding test, the first test occurred under the VI 30-s schedule for Rat 4 and under the VI 120-s schedule for Rats 2, 11, and 14. In the second determination of both the 2% and 4% prefeeding tests, the first test occurred under the VI 30-s schedule for Rat 4 and under the VI 120-s schedule for Rat 11. For Rat 2 the first extinction test occurred under the VI 120-s schedule, and for Rats 11, 4, and 14 the first extinction test occurred under the VI 30-s schedule.

Part 2 (Group B): VI 30-s extinction and VI 120-s extinction schedules alternating each day. This condition was a replication of Part 1 for Rats 6, 16, 7, and 18, except that the multiple VI 30-s extinction and multiple VI 120-s extinction schedules alternated each day. Resistance-to-change tests were conducted as previously described for Group A in Part 2. In the initial determination of the 2% and 4%

prefeeding tests, the first test occurred under the VI 30-s schedule for Rats 6, 7, and 18 and under the VI 120-s schedule for Rat 16. In the second determination of the 2% prefeeding test, the first test occurred under the VI 30-s schedule for Rats 6, 7, and 16 and under the VI 120-s schedule for Rat 18. In the second determination of the 4% prefeeding test, the first test occurred under the VI 30-s schedule for Rats 6 and 7 and under the VI 120-s schedule for Rats 16 and 18. For Rat 7 the first extinction test occurred under the VI 30-s schedule, and for Rats 6, 16, and 18 the first extinction test occurred under the VI 120-s schedule.

Part 3 (Group A): VI 30-s and VI 120-s schedules alternating within the session. Rats 2, 11, 4, and 14 responded under a multiple VI 30-s VI 120-s schedule. Components (3 min long) alternated within the session. Components 1 and 2 were scheduled in pairs, and one of the two components within each pair was chosen randomly to occur first. As described in Part 1, the steady houselight signaled Component 1, and the flashing (0.1 s off, 0.1 s on) houselight signaled Component 2. Also as in Part 1, Component 1 was VI 30 s for Rats 2 and 11 and VI 120 s for Rats 4 and 14. Each component was separated by a 30-s timeout, during which the houselight was turned off and lever presses had no scheduled consequences. Sessions terminated after each component had occurred 12 times. After responding stabilized, resistance-to-change tests were conducted as described above. Because both VI schedules alternated under the multiple schedule, prefeeding and extinction tests were conducted on both schedules within the same session.

Part 3 (Group B): VI 30-s and VI 120-s schedules alternating within the session. Rats 6, 16, 7, and 18 were trained and tested under the same multiple VI 30-s VI 120-s schedule as the rats in Part 3, Group A. The 1.0-s flashing houselight was not used in Part 3. Resistance-to-change tests were conducted as described above. Rat 18 was tested only once with 4% prefeeding.

RESULTS

Response rate was calculated by dividing total responses emitted under a VI schedule by the time (not including feeder cycles) spent

in that schedule. For Group A (Parts 1 and 2) the VI schedule was in effect for the entire session. For Group B (Parts 1 and 2) the VI schedule alternated within the session with an extinction schedule. Response rate during extinction was very low for all rats and was not included in any analysis (see the Appendix for response rates in the extinction component). In Part 3, the VI 30-s and VI 120-s schedules alternated within the session as a multiple schedule. The result of each resistance-to-change test was expressed as a ratio of the response rate during a test session to the response rate during the session that immediately preceded the test (proportion of baseline), because the momentum model predicts changes relative to baseline response rates. Values below 1.0 indicate that response rates were reduced during a test relative to baseline. For redeterminations of prefeeding tests, the arithmetic mean of the two proportions of baseline was used in the analyses. Absolute response rates during each resistance-to-change test session and the mean response and reinforcement rates of the five baseline sessions that preceded the first test are presented in the Appendix.

Prefeeding. Figures 1 and 2 present the effects of prefeeding on the proportion-of-baseline response rates for individual rats under the VI 30-s and VI 120-s schedules for Groups A and B, respectively. Prefeeding reduced response rates for most rats, and greater reductions usually occurred with 4% than with 2% prefeeding (see plots for Rats 18 and 11 in Part 3 for exceptions). The critical comparison is the proportion-of-baseline response rates under the VI 30-s and VI 120-s schedules: The behavioral momentum model predicts greater resistance to prefeeding under the VI 30-s schedule. A between-subjects analysis of the data showed that there were no consistent differences in the proportion-of-baseline response rates between VI 30-s and VI 120-s schedules for both Groups A and B when the schedules were run in successive conditions (left panel of Figures 1 and 2, respectively). When the VI 30-s and VI 120-s schedules alternated each day and were not accompanied by an extinction schedule (Figure 1, center panel), there were no consistent differences in the proportion-of-baseline response rates between the VI 30-s and VI 120-s schedules. However, when the VI schedules alternated each

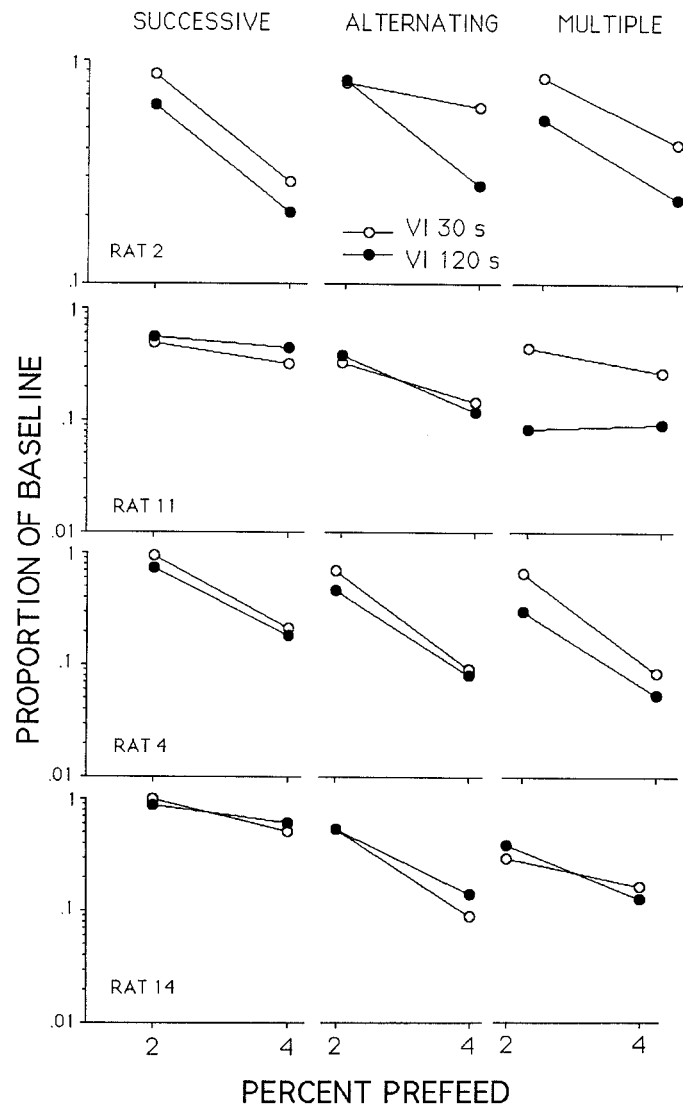


Fig. 1. Group A. The ratio of response rate during a resistance-to-prefeeding test to the response rate on the immediately preceding baseline session (proportion of baseline). Rats were prefed 2% and 4% of their free-feeding body weights before each test session. In Part 1 (left panel) the VI 30-s and VI 120-s schedules of reinforcement were conducted in successive conditions. In Part 2 (center panel) the VI 30-s and VI 120-s schedules alternated each day. In Part 3 (right panel) the VI schedules alternated within the session as a multiple schedule. The vertical axes are logarithmic; the slope of each line indicates the relative change in response rate from 2% to 4% prefeeding.

day and an extinction component accompanied each schedule (Figure 2, center panel), resistance to prefeeding was greater for responding under the VI 30-s schedule in seven of eight comparisons. Likewise, when the VI 30-s and VI 120-s schedules alternated within the session as a multiple schedule, resistance to prefeeding was greater for responding under the VI 30-s schedule in seven of eight com-

parisons in Group A (Figure 1, right panel) and in seven of eight comparisons in Group B (Figure 2, right panel). These trends can be seen clearly in the average prefeeding data in Figure 3 (top panels). For the sake of simplicity and because no consistent differences were found between Groups A and B in Parts 1 and 3, the data for Groups A and B were combined in Figure 3, and each part was subjected to 2

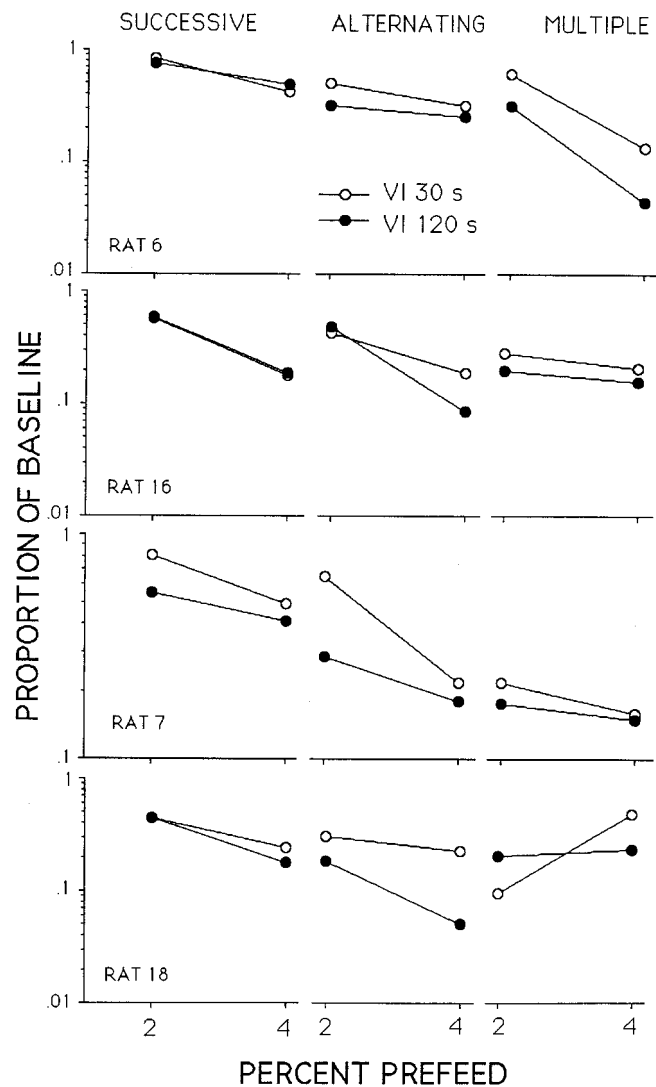


Fig. 2. Group B. The ratio of response rate during a resistance-to-prefeeding test to the response rate on the immediately preceding baseline session (proportion of baseline). In Part 1 (left panel) and Part 2 (center panel), an extinction schedule alternated within the session with the VI 30-s and the VI 120-s schedules. Details as in Figure 1.

$\times 2$ completely repeated measures analyses of variance, with schedule (VI 30 s and VI 120 s) and percentage prefeeding (2% and 4%) as factors. Figure 3 shows that when the schedules were studied in successive conditions (top left panel), there was slightly greater resistance to prefeeding for responding under the VI 30-s schedule than under the VI 120-s schedule in the 2% prefeeding test but not in the 4% test: The Schedule \times Percentage Prefeeding interaction was significant, $F(1, 7) = 9.89$, $p = .02$, but the main effect of VI schedule was not

significant, $F(1, 7) = 2.19$. This significant interaction in the group data in Part 1 does not reflect the lack of consistent differences between the VI 30-s and VI 120-s schedules observed in the individual data (see Figures 1 and 2, left panels). Significantly greater resistance to prefeeding in the VI 30-s component was observed when the schedules alternated each day, $F(1, 7) = 9.18$, $p = .02$, and when the schedules alternated within the session, $F(1, 7) = 11.63$, $p = .01$.

When the data were examined within sub-

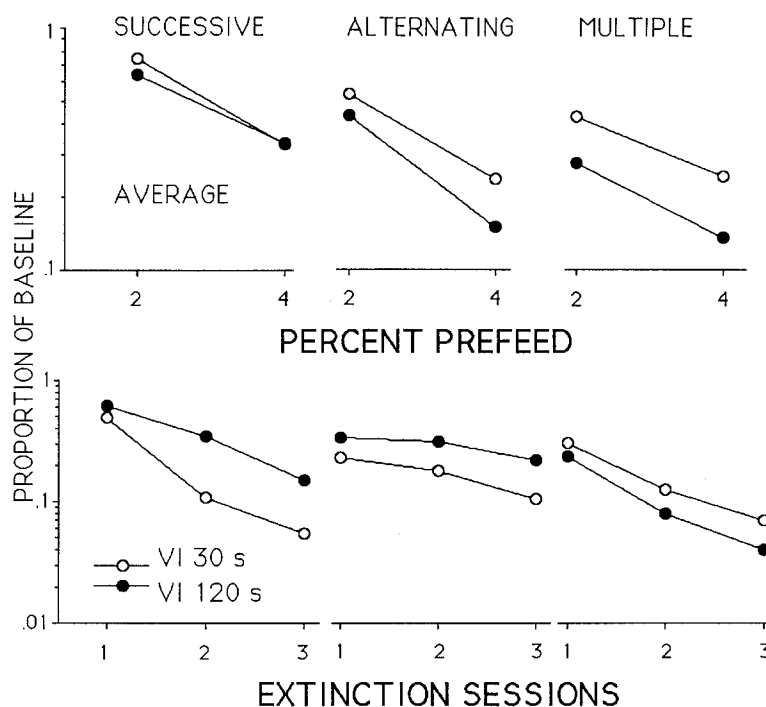


Fig. 3. Average data. Proportion of baseline response rates during prefeeding tests (top panel) and extinction tests (bottom panel) when the VI 30-s and VI 120-s schedules were conducted in successive conditions (Part 1, left panel), when they alternated each session (Part 2, center panel), and when they alternated within the session as a multiple schedule (Part 3, right panel). Data for each part are averaged across all 8 rats (Groups A and B combined). Details as in Figure 1.

jects, rather than between subjects, across Parts 1, 2, and 3, similar trends were apparent, but the data were not consistent for every subject. Rats 2, 11, and 4 (Figure 1) and Rats 6 and 16 (Figure 2) showed little, if any, difference in resistance to prefeeding between the VI 30-s and VI 120-s schedules in Part 1 and showed greater resistance to prefeeding in the VI 30-s schedule in Part 3. Rats 14, 7, and 18 did not show consistently greater resistance to prefeeding under the VI 30-s schedule across Parts 1, 2, and 3.

Another trend that was observed within subjects was that resistance to change decreased for several rats under both VI 30-s and VI 120-s schedules across Parts 1, 2, and 3. For the 2% prefeeding tests, resistance to change decreased steadily across Parts 1, 2, and 3 under the VI 30-s schedule for 5 of 8 rats (Rats 4, 14, 16, 7, and 18) and decreased steadily under the VI 120-s schedule for 5 of 8 rats (Rats 11, 4, 14, 16, and 7). For the 4% prefeeding tests, resistance to change decreased steadily across all three parts under

the VI 30-s schedule for 2 of 8 rats (Rats 6 and 7) and under the VI 120-s schedule for 4 of 8 rats (Rats 11, 4, 6, and 7). The decrease in resistance to change across Parts 1, 2, and 3 that was observed in some rats is evident in the average data (Figure 3, top panel).

Extinction. Figures 4 and 5 are organized like Figures 1 and 2 but present the effects of extinction on the proportion-of-baseline response rates for individual rats. Response rates declined across the three extinction sessions for most rats. This decline was less evident in Part 2 than in Parts 1 and 3. The smaller decrease was most likely caused by not having three consecutive extinction sessions in Part 2. When examining the data between subjects, resistance to extinction in Part 1 (successive schedules) and Part 2 (schedules alternating daily) was greater under the VI 120-s schedule than under the VI 30-s schedule for both Group A (Figure 4, left and center panels) and Group B (Figure 5, left and center panels): For 8 rats that were exposed to three extinction sessions in Parts

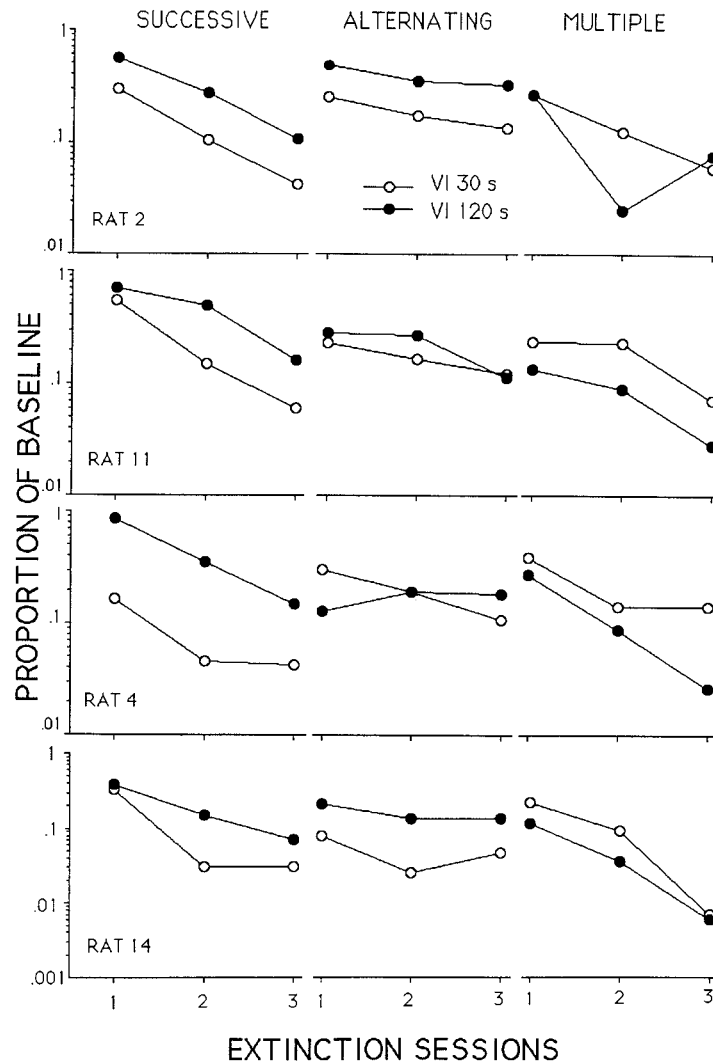


Fig. 4. Group A. The ratio of response rate during three successive resistance-to-extinction test sessions to the rate on the immediately preceding baseline session (proportion of baseline). Details as in Figure 1.

1 and 2 combined, resistance to extinction was greater under the VI 120-s schedule in 42 of 48 comparisons. In Part 3 (VI schedules alternating within the session) resistance to extinction was greater under the VI 30-s schedule than under the VI 120-s schedule: Greater resistance to extinction was observed under the VI 30-s schedule in 10 of 12 comparisons for Group A (Figure 4, right panel) and in 8 of 12 comparisons for Group B (Figure 5, right panel). Because no consistent differences in resistance to extinction were observed between Groups A and B, their proportion-of-baseline data were averaged

and are presented in Figure 3 (bottom panel). These data were subjected to 2×3 completely repeated measures analyses of variance, with schedule (VI 30 s and VI 120 s) and extinction sessions (1, 2, and 3) as factors. Resistance to extinction was significantly greater under the VI 120-s schedule when the VI 30-s and VI 120-s schedules were studied in successive conditions, $F(1, 7) = 13.10$, $p = .01$ (bottom left panel), and when they alternated each session, $F(1, 7) = 13.10$, $p = .01$ (bottom middle panel). However, when the VI 30-s and VI 120-s schedules alternated within the session (bottom right panel), re-

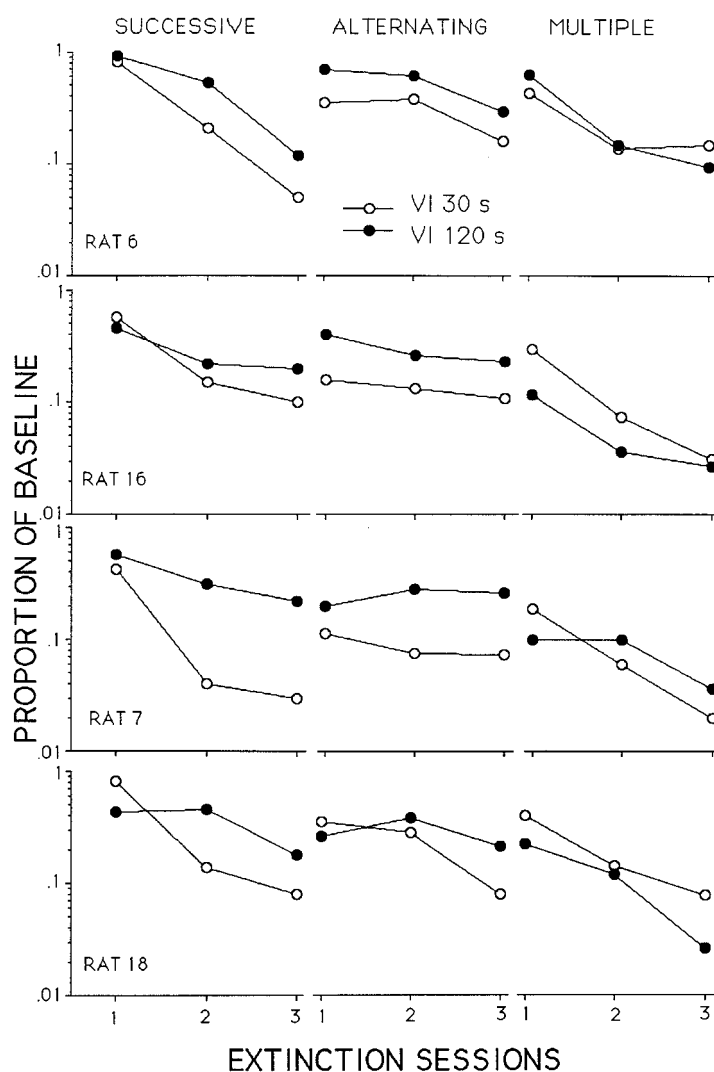


Fig. 5. Group B. The ratio of response rate during three successive resistance-to-extinction test sessions to the rate on the immediately preceding baseline session (proportion of baseline). In Part 1 (left panel) and Part 2 (center panel) an extinction schedule alternated within the session with the VI 30-s and the VI 120-s schedules. Details as in Figure 1.

sistance to extinction was significantly greater under the VI 30-s schedule, $F(1, 7) = 6.85$, $p = .03$.

When the extinction data were analyzed within subjects across Parts 1, 2, and 3, similar trends were apparent: Resistance to extinction was greater under the VI 120-s schedule during Parts 1 and 2 and greater under the VI 30-s schedule during Part 3. However, this trend was not observed in every rat in every extinction session. For example, Rat 2 (Figure 4) showed greater resistance to extinction

under the VI 120-s schedule during Parts 1 and 2, but showed greater resistance to extinction under the VI 30-s schedule only in Session 2 of Part 3. Similarly in Part 3, Rat 6 (Figure 5) showed greater resistance to extinction only under the VI 30-s schedule in Session 3.

The decrease in resistance to prefeeding that was observed in some rats across Parts 1 to 3 was also evident in the resistance-to-extinction data (Figures 4 and 5). When resistance to extinction was compared in Parts 1

Table 2

Weighted-mean proportion of baseline response rate (\bar{p}) of the 2% and 4% prefeeding sessions and the three extinction sessions for each rat under the VI 30-s and VI 120-s schedules in Parts 1, 2, and 3 of the experiment. Mean values for each schedule are also presented.

Part	Rat	Prefeeding		Extinction	
		VI 30 s	VI 120 s	VI 30 s	VI 120 s
1	2	.48	.35	.11	.24
	11	.38	.49	.17	.36
	4	.45	.37	.06	.33
	14	.68	.69	.08	.15
	6	.56	.58	.23	.39
	16	.60	.46	.10	.31
	7	.31	.32	.20	.25
	18	.31	.27	.22	.32
	<i>M</i>	.47	.44	.15	.29
2	2	.68	.46	.17	.37
	11	.21	.21	.16	.19
	4	.29	.21	.17	.18
	14	.24	.27	.04	.15
	6	.38	.28	.27	.47
	16	.36	.22	.08	.26
	7	.26	.22	.12	.27
	18	.25	.10	.19	.29
	<i>M</i>	.33	.25	.15	.27
3	2	.56	.34	.12	.09
	11	.33	.09	.15	.07
	4	.28	.14	.18	.09
	14	.20	.21	.07	.03
	6	.30	.14	.19	.20
	16	.18	.16	.06	.07
	7	.23	.17	.09	.05
	18	.35	.22	.15	.09
	<i>M</i>	.30	.18	.13	.09

and 3 for individual rats (Part 2 was not included in this analysis because extinction was not conducted on consecutive sessions) resistance to extinction under the VI 120-s schedule decreased from Part 1 to Part 3 in all three extinction sessions for all 8 rats. Under the VI 30-s schedule, resistance to extinction decreased from Part 1 to Part 3 in 6 of the 8 rats, but only in the first extinction session: Consistent decreases in resistance to extinction were not evident in Sessions 2 or 3. This decreasing trend was also evident in the average resistance to extinction for VI 120 s (Figure 3, bottom panel).

Weighted mean proportion (\bar{p}) of baseline. A quantitative summary of the data from the prefeeding and extinction tests is presented in Table 2. These data are weighted mean proportion-of-baseline response rates (Nevin et al., 1981) that combine proportion-of-baseline response rates under the 2% and 4% pre-

feeding tests into one value, and combine the three extinction sessions into one value. These \bar{p} values give greater weight to operations that are intended to produce greater response reductions. Thus, \bar{p} is a summary measure of resistance to change, where a value of 0 indicates complete cessation of responding during each resistance-to-change test and a value of 1.0 indicates no change in response rates. For example, if proportion-of-baseline response rates were 0.8 under 2% prefeeding and 0.3 under 4% prefeeding, then $\bar{p} = [(0.8 * 2) + (0.3 * 4)] / (2 + 4) = 0.47$.

The \bar{p} values under VI 30-s and VI 120-s schedules (Groups A and B combined) shown in Table 2 were compared with dependent t tests. No consistent differences in resistance to prefeeding were observed between the VI 30-s and VI 120-s schedules when the schedules were studied in successive conditions: Part 1, $t(7) = 1.00$. Resistance to prefeeding was greater under the VI 30-s schedule when the schedules alternated each day, Part 2, $t(7) = 2.98$, $p = .02$, and when they were presented in the multiple-schedule context, Part 3, $t(7) = 3.76$, $p = .007$. Resistance to extinction was greater under the VI 120-s schedule than under the VI 30-s schedule in Part 1, $t(7) = 5.59$, $p = .001$, and Part 2, $t(7) = 4.71$, $p = .002$, but was greater under the VI 30-s schedule in Part 3, $t(7) = 3.06$, $p = .018$.

The decrease in resistance to prefeeding and extinction across Parts 1, 2, and 3 that was observed in several rats' proportion-of-baseline data (see Figures 1 to 5) can be seen in the weighted-means data. Consistent decreases across Parts 1, 2, and 3 in resistance-to-prefeeding weighted means were observed in 5 of 8 rats (Rats 4, 14, 6, 16, and 7) under the VI 30-s schedule and in 6 of 8 rats (Rats 11, 4, 14, 6, 16, and 7) under the VI 120-s schedule. Resistance-to-extinction weighted means decreased from Parts 1 to 3 (Part 2 was not included in this analysis) in 6 of 8 rats under the VI 30-s schedule and in 8 of 8 rats under the VI 120-s schedule.

DISCUSSION

The behavioral momentum model predicts a direct relationship between rate of reinforcement and resistance to change (e.g., Nevin, 1974, 1979). Cohen et al. (1993) found

a direct relationship between these two variables under multiple schedules of reinforcement but not under simple schedules of reinforcement. The purpose of the present study was to investigate variables that might account for the failure to find data consistent with the momentum model in simple-schedule contexts. It was suggested that the frequent alternations of high and low rates of reinforcement within a session might be necessary to obtain a direct relationship between rate of reinforcement and resistance to change. It was also suggested that differences in the stimulus-reinforcer relations in multiple and simple schedules might have contributed to the failure to find data consistent with the behavioral momentum model in simple schedules.

When VI 30-s and VI 120-s schedules were examined in successive conditions (Part 1) and when they alternated each day (Part 2), resistance to extinction was greater under the VI 120-s schedule of reinforcement than under the VI 30-s schedule, a finding consistent with the partial reinforcement extinction effect but contrary to the behavioral momentum model. When the VI 30-s and VI 120-s schedules alternated within the session as a multiple schedule (Part 3), resistance to extinction was greater under the VI 30-s schedule, consistent with the behavioral momentum model. These effects were evident in the between-subjects analysis of the individual data, in the statistical analyses, and in the weighted-mean proportions of baseline (Table 2). These effects were also seen when the data were analyzed within subjects across Parts 1, 2, and 3, but not every rat showed these trends in every extinction session.

When the schedules were studied in successive conditions (Part 1), prefeeding did not produce a direct relationship between rate of reinforcement and resistance to change: The individual subjects' proportion-of-baseline data and \bar{p} values did not show consistent differences between the VI 30-s and VI 120-s schedules. When the VI 30-s and VI 120-s schedules alternated within the session as a multiple schedule (Part 3), resistance to prefeeding was greater under the VI 30-s schedule, consistent with the momentum model. When the VI 30-s and VI 120-s schedules alternated each day (Part 2), a more complex picture emerged: Whereas the anal-

ysis of variance of proportions of baseline and t tests comparing \bar{p} values indicated greater resistance to prefeeding under the VI 30-s schedule than under the VI 120-s schedule, the individual data (Figures 1 and 2) showed that resistance to prefeeding was only greater under the VI 30-s schedule in Group B, when the VI schedules were accompanied by an extinction schedule. In summary, when VI 30-s and VI 120-s schedules of reinforcement alternated frequently within a session as a multiple schedule (Part 3), tests of prefeeding and extinction produced data that were consistent with the behavioral momentum model (i.e., a direct relationship between rate of reinforcement and resistance to change). When the two schedules were examined over successive conditions (Part 1), tests of resistance to change did not support the behavioral momentum model. When the two schedules alternated each day (Part 2), extinction data did not support, and prefeeding data provided partial support for, the momentum model.

There are significant differences in the stimulus-reinforcer relations between simple and multiple schedules. A multiple schedule arranges conditions of differential reinforcement. One stimulus signals the availability of a high rate of reinforcement, and a second stimulus signals the availability of a lower rate of reinforcement. Simple schedules arrange conditions of nondifferential reinforcement, because only one stimulus (e.g., some part of the stimulus context) is present during reinforced responding, and unreinforced responding in the absence of that stimulus does not occur, unless one considers unrecorded responding in the darkened chamber before and after a session or in an animal's home cage. Pavlovian stimulus-reinforcer relations (Nevin, 1992) are considerably different under differential and nondifferential reinforcement conditions (see below), and these differences could contribute to the differences in behavioral mass that have been reported under simple and multiple schedules (e.g., Cohen et al., 1993). There are also stimulus control issues that arise when conditions of differential and nondifferential reinforcement are compared. In multiple schedules, two discriminative stimuli come to control behavior because they are the only stimuli that reliably differentiate between the two rates of reinforcement. Differential reinforcement in

a multiple schedule makes it likely that the stimulus that controls responding in each schedule is the same type of stimulus (e.g., both key colors), and that the stimulus is a unified stimulus in that it is not a composite of several stimuli (e.g., key color, grid floor, and fan cover). The nondifferential reinforcement conditions in simple schedules make it difficult to specify what stimuli control responding or the extent of the stimulus control. Whereas some research has demonstrated that nondifferential reinforcement in simple schedules may lead to stimulus control by visual and auditory stimuli (e.g., Guttman & Kalish, 1956; Rudolph & Van Houten, 1977), other research has shown that this does not always occur (e.g., H. M. Jenkins & Harrison, 1960) or that it occurs to a lesser degree with nondifferential reinforcement than with differential reinforcement (e.g., DePaulo, DeWald, & Yarczower, 1977). It is also not clear if the stimulus that controls responding in simple schedules is a unified stimulus or if several stimuli share control over behavior (e.g., Wilkie & Masson, 1976). In short, differences in the Pavlovian stimulus-reinforcer relations and related issues of stimulus control in simple schedules (nondifferential reinforcement) and multiple schedules (differential reinforcement) might contribute to the reported differences in resistance to change. In Part 1 of the present experiment, 4 rats (Group A) were exposed to simple VI 30-s and VI 120-s schedules that were arranged nondifferentially in successive conditions. For 4 other rats (Group B) the VI 30-s and VI 120-s schedules were also studied in successive conditions, but each schedule alternated within the session with an extinction schedule. Thus, for rats in Group B, both VI 30-s and VI 120-s schedules were arranged in a context of differential reinforcement, yet they were temporally separated as in simple-schedule experiments. In Part 1 there were no consistent differences in resistance to change between Groups A and B, suggesting that the failure to find data consistent with the behavioral momentum model in simple schedules (e.g., Clark, 1958; Cohen et al., 1990, 1993) cannot be attributed to the absence of differential reinforcement per se or a failure to have strong stimulus control. The data suggest that the behavioral momentum model will successfully predict behavioral

mass under conditions of differential reinforcement if the different rates of reinforcement are contrasted within the same session. Data from Group B in Part 2 further suggest that with tests of prefeeding and conditions of differential reinforcement, behavioral mass may be predicted from the momentum model when different rates of reinforcement are contrasted on alternate days.

Nevin (1984, 1992; Nevin et al., 1987, 1990) has emphasized the importance of Pavlovian stimulus-reinforcer contingencies in determining behavioral mass. The stimulus-reinforcer contingency is determined by the ratio of the rate of reinforcement in the presence of a stimulus to the rate of reinforcement in the presence and the absence of the stimulus (Nevin, 1992). In a multiple schedule, the average rate of reinforcement in one component is divided by the rate of reinforcement averaged over the entire session to determine the stimulus-reinforcer contingency in that component. For example, in a multiple VI 30-s VI 120-s schedule with 3-min components and a 30-s timeout separating components, the rate of reinforcement in the VI 30-s component is 120 reinforcers per hour, and the rate of reinforcement for the entire session is 64.28 reinforcers per hour. (In one cycle of two 3-min components plus two 30-s timeouts, 7.5 reinforcers could be collected on average in a 7-min cycle, yielding 64.28 reinforcers per hour over the entire session.) The contingency ratio for the VI 30-s component is thus 1.87 ($120/64.28$), and the ratio for the VI 120-s component is 0.47 ($30/64.28$). The stronger contingency ratio under the VI 30-s schedule predicts greater resistance to change in that component compared to the VI 120-s schedule, a prediction that is consistent with the data from Part 3 of this experiment.

Applying Nevin's (1992) contingency model to Group B in Parts 1 and 2 of the present experiment raises some interesting questions. Group B was trained under a multiple VI 30-s extinction schedule in one condition and a multiple VI 120-s extinction schedule in another condition, and no consistent differences in resistance to change were observed between the two conditions in Part 1. Interestingly, Nevin's model predicts equal resistance to change in the VI 30-s and VI 120-s schedules under these conditions: The con-

tingency ratio in the VI 30-s component of the multiple VI 30-s extinction schedule is 2.33 (120 reinforcers per hour in the VI 30-s component divided by a total-session reinforcer rate of 51.43 reinforcers per hour). The contingency ratio in the VI 120-s component of the multiple VI 120-s extinction schedule is also 2.33 (30 reinforcers per hour in the VI 120-s component divided by a total-session reinforcer rate of 12.86 reinforcers per hour). Consistent with this prediction, equal resistance to prefeeding was observed between the VI 30-s and VI 120-s schedules in Part 1. Contrary to this prediction, however, rats in Part 2 (Group B) showed greater resistance to prefeeding under the VI 30-s schedule than under the VI 120-s schedule. In addition, resistance to extinction in Parts 1 and 2 was greater under the VI 120-s schedule than under the VI 30-s schedule.

Applying Nevin's (1992) contingency model to the simple schedules used in Group A is problematic. The model calls for dividing the rate of reinforcement in the presence of a stimulus by the rate of reinforcement in the presence and the absence of the stimulus. In a simple VI schedule it is unclear what constitutes the denominator of this ratio (i.e., what is the rate of reinforcement in the absence of the stimulus that signals the VI schedule?). Clearly, reinforcement is present in the home cage outside of the experimental session (e.g., postsession feeding, drinking, grooming, handling), but exactly how to calculate this rate of reinforcement is unclear, and what effect, if any, these reinforcers might have on responding inside the operant chamber has not been determined. In simple schedules, therefore, it is unclear if the reinforcement rate outside the chamber can serve as the background against which reinforcement rate inside the chamber is compared. If reinforcers outside of the operant chamber do affect responding inside of the chamber, then under a multiple schedule these effects should be the same on both components of the multiple schedule, allowing for calculations of behavioral mass in one component of the multiple schedule relative to the other component. Assume for the moment that in simple schedules the time outside the chamber serves as the background against which responding inside the chamber is compared, and further assume that the rate

of reinforcement outside the chamber is zero. Under these conditions the denominator in Nevin's (1992) contingency ratio would be the number of reinforcers obtained inside of the chamber divided by 24 hr. Under a simple VI 30-s schedule in a 72-min session, the contingency ratio would be 20 (120 reinforcers per hour during the session divided by 6 reinforcers per hour over 24 hr), and under a simple VI 120-s schedule the ratio would also be 20 (30 reinforcers per hour during the session divided by 1.5 reinforcers per hour over 24 hr). This analysis suggests that not only should simple VI 30-s and VI 120-s schedules have the same behavioral mass but that their mass should be greater than the mass observed in components of multiple schedules (i.e., a contingency ratio of 20 in a simple VI 30-s schedule compared to a ratio of 1.87 for a VI 30-s schedule when it is presented in a multiple VI 30-s VI 120-s context). This analysis is certainly speculative and awaits data on how reinforcers outside the operant chamber affect behavior inside the chamber.

One aspect of the data that should be noted is the decrease in resistance to prefeeding and resistance to extinction that was observed in several animals across Parts 1, 2, and 3. Because all rats were studied in the same order, and Part 1 was not replicated at the end of the experiment, it is not clear if this decrease in resistance to change simply represents an order effect or if resistance to change under simple schedules is greater than under multiple schedules (note the speculation above). Lentz and Cohen (1980) showed that increasing the length of training under a schedule of reinforcement leads to greater, not less, resistance to change, suggesting that the decrease in resistance to change across conditions in the present experiment was most likely not an order effect. There are few data available that have compared resistance to change in simple and multiple schedules under comparable training and testing conditions. In one comparison, Cohen et al. (1993) measured resistance to prefeeding and resistance to extinction in one group of rats responding under simple FI 30-s and FI 120-s schedules and in another group of rats responding under a multiple FI 30-s FI 120-s schedule. Comparisons of the \bar{p} values reported by Cohen et al. show that re-

sistance to prefeeding was significantly greater in the simple-schedule context than in the multiple-schedule context for the FI 30-s schedule, $t(12) = 2.744$, $p = .02$, and the FI 120-s schedule, $t(12) = 3.51$, $p = .004$. However, resistance to extinction under the FI 30-s schedule was significantly greater in the multiple-schedule context than in the simple-schedule context, $t(12) = 2.393$, $p = .034$, and no significant differences between contexts were observed under the FI 120-s schedule, $t(12) = 0.31$. Only further research will determine whether absolute resistance to change differs under a schedule of reinforcement depending on whether the schedule is presented in simple- or multiple-schedule contexts.

Another aspect of the present data that might have implications for the behavioral momentum model is the differential effects of prefeeding and extinction in Parts 1 and 2. In Part 1 there were no differences in resistance to prefeeding between the VI 30-s and the VI 120-s schedules, but resistance to extinction was greater in the VI 120-s schedule. In Part 2, there were no differences in resistance to prefeeding between the VI 30-s and the VI 120-s schedules for the rats in Group A. However, the rats in Group B showed more resistance to prefeeding in the VI 30-s schedule, but again resistance to extinction was greater in the VI 120-s schedule. Only in Part 3 were the effects of prefeeding and extinction comparable (i.e., greater resistance to change in the VI 30-s schedule). These data suggest that prefeeding and extinction might not be equivalent tests of resistance to change, and that the behavioral momentum model will have to account for the differential effects of different tests of resistance to change (see also Cohen et al., 1993; Harper & McLean, 1992).

The present data are consistent with the results of several other studies that have failed to find a direct relationship between rate of reinforcement and resistance to change in simple schedules (Ayres, 1968; Ayres & Quinsey, 1970; Clark, 1958; Cohen et al., 1990, 1993; Hancock & Ayres, 1974; Leslie, 1977). For example, Clark (1958) trained three independent groups of rats to respond under VI 1-min, VI 2-min, or VI 3-min schedules of reinforcement. Feeding subjects before the experimental session reduced response rates

equally in all three groups relative to baseline. Hancock and Ayres (1974) had rats lick an 8% and a 32% sucrose solution from a sipping tube on alternate days. A tone paired with shock suppressed lick rates equally under both reinforcement magnitudes. Furthermore, studies using simple schedules have shown an inverse relation between rate of reinforcement and resistance to extinction (i.e., the partial reinforcement extinction effect, see Mackintosh, 1974), even when subjects were given extensive training and the data were analyzed as proportions of baseline (Cohen et al., 1990, 1993).

To complicate matters, the present data are inconsistent with the results of studies that have found a direct relation between rate of reinforcement and resistance to change in simple schedules (Blackman, 1968; Boren, 1961; Church & Raymond, 1967; Millenson & de Villiers, 1972). For example, Church and Raymond trained independent groups of rats to respond under a VI 12-s or a VI 5-min schedule of reinforcement and later superimposed response-dependent shock on responding. Consistent with the behavioral momentum model, response suppression was greater under the VI 5-min schedule. Nevin (1988) also reviewed research related to the partial reinforcement extinction effect and showed that many studies using independent groups of subjects reported a direct relation between rate of reinforcement and resistance to extinction when subjects had extensive training and the data were analyzed as proportions of baseline rather than as the total number of responses to extinction. In addition, Nevin (1988) described a procedure with pigeons that was similar in some respects to Part 2 of the present experiment and found data consistent with the behavioral momentum model. In Nevin's procedure, a mixed VI 30-s extinction schedule alternated each day with a mixed CRF extinction schedule. Each session started with the VI 30-s or the CRF schedule, and following a brief blackout the session ended with a period of nonreinforcement. The VI and CRF schedules were each signaled by a different key color, but within each session the key color was unchanged from the first part of the session (VI or CRF) to the second part of the session (extinction). After extensive training resis-

tance to extinction was greater following the CRF schedule than following the VI schedule.

It is unclear why the present study and others (e.g., Clark, 1958; Cohen et al., 1990, 1993) failed to find data consistent with the behavioral momentum model with simple schedules of reinforcement, whereas some studies (e.g., Church & Raymond, 1967; Millenson & de Villiers, 1972; Nevin, 1988) have found data consistent with the model. One variable that might contribute to the relation between rate of reinforcement and resistance to change in simple schedules is the range of reinforcement rates compared across successive conditions or in independent groups of subjects. Many studies that found a relation consistent with the behavioral momentum model used a range of reinforcement schedules that compared very high reinforcement rates with much lower reinforcement rates, for example, conditions that ranged from CRF and VI 12-s schedules to FI 2-min and VI 30-s schedules (Boren, 1961; Carlton, 1961; Church & Raymond, 1967; P. E. Jenkins, 1978; Nevin, 1988). Studies that generated results inconsistent with the behavioral momentum model included schedules that did not arrange such high rates of reinforcement. For example, VI 1-min, FR 40, VI 30-s, and VI 30-s schedules produced the highest rates of reinforcement in the Clark (1958), Cohen et al. (1990, 1993), and present studies, respectively. Although this explanation might not account for all of the data (e.g., cf. Millenson & de Villiers, 1972, with Hancock & Ayres, 1974, and see Blackman, 1968), further research comparing a wide range of reinforcement rates in simple schedules might be revealing.

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APPENDIX

Responses per minute in resistance-to-change test sessions, and the mean response rates (B/min) and reinforcement rates (R/hr) for the last five baseline sessions before the first resistance-to-change test under the VI 30-s and VI 120-s schedules in Part 1 (schedules in successive conditions), Part 2 (schedules alternate each session), and Part 3 (schedules alternate within the session). B1 shows responses per minute under the VI schedules. B2 shows responses per minute in the added extinction component for Rats 6, 16, 7, and 18 in Parts 1 and 2. Rats 2, 11, 4, and 14 did not have the added extinction component.

Rat	Part	VI (s)	Baseline			Prefeeding (%)		Extinction sessions		
			B1/min	B2/min	R/hr	2	4	1	2	3
2	1	30	106.0		112.0	92.0	30.0	32.0	11.4	4.5
		120	44.0		28.0	30.0	9.0	27.1	13.4	5.3
	2	30	81.0		110.0	58.0	35.0	19.2	13.1	10.2
		120	61.0		28.0	49.0	10.0	18.4	13.3	12.3
	3	30	95.0		110.0	85.0	42.0	24.7	11.5	5.5
		120	64.0		26.0	38.0	13.0	14.2	1.3	4.1
11	1	30	30.0		106.0	15.0	9.0	20.8	5.6	2.1
		120	8.0		24.0	5.0	4.0	7.3	5.1	1.7
	2	30	24.0		101.0	9.0	4.0	7.3	5.2	3.9
		120	15.0		28.0	5.0	2.0	4.2	4.0	1.7
	3	30	40.0		19.0	17.0	12.0	8.8	8.6	2.7
		120	98.0		22.0	2.0	2.0	2.4	1.6	0.5
4	1	30	59.0		103.0	53.0	11.0	8.8	2.4	2.2
		120	9.0		26.0	6.0	2.0	8.6	3.5	1.5
	2	30	24.0		99.0	17.0	2.0	6.6	4.1	2.3
		120	15.0		28.0	7.0	1.0	2.2	3.3	3.1
	3	30	22.0		90.0	16.0	2.0	10.8	3.9	3.9
		120	18.0		24.0	6.0	1.0	5.3	1.7	0.5
14	1	30	59.0		107.0	56.0	28.0	20.9	1.8	2.1
		120	27.0		28.0	21.0	14.0	6.3	2.5	1.2
	2	30	103.0		109.0	59.0	10.0	9.4	3.0	5.6
		120	35.0		27.0	17.0	5.0	6.9	4.5	4.5
	3	30	111.0		101.0	34.0	15.0	21.2	8.8	0.7
		120	54.0		28.0	22.0	7.0	7.2	2.3	0.4
6	1	30	34.0	1.5	102.0	29.0	14.0	31.4	7.9	2.0
		120	17.0	1.8	26.0	12.0	8.0	12.7	7.2	1.7
	2	30	18.0	0.6	98.0	11.0	7.0	6.5	6.9	3.0
		120	13.0	0.6	26.0	4.0	3.0	8.7	7.7	3.8
	3	30	25.0		96.0	15.0	3.0	16.9	5.7	6.0
		120	8.0		21.0	2.0	1.0	7.3	1.7	1.1
16	1	30	45.0	0.5	102.0	28.0	8.0	20.2	5.2	3.3
		120	4.0	0.5	22.0	3.0	1.0	2.5	1.2	1.1
	2	30	27.0	0.0	97.0	12.0	5.0	4.1	3.4	2.8
		120	11.0	0.1	24.0	6.0	1.0	3.7	2.4	2.1
	3	30	28.0		89.0	8.0	6.0	10.4	2.6	1.1
		120	9.0		13.0	2.0	1.0	1.3	0.4	0.3
7	1	30	39.0	4.0	117.0	32.0	19.0	17.9	1.9	1.5
		120	18.0	4.3	26.0	10.0	7.0	11.4	6.0	4.4
	2	30	40.0	0.6	107.0	25.0	10.0	4.2	2.8	2.7
		120	15.0	0.5	25.0	5.0	3.0	2.2	3.1	2.9
	3	30	47.0		104.0	10.0	7.0	8.7	2.6	1.0
		120	10.0		23.0	2.0	2.0	1.1	1.1	0.4
18	1	30	28.0	1.1	103.0	12.0	8.0	25.6	4.4	2.6
		120	12.0	1.1	27.0	4.0	2.0	5.4	5.8	2.3
	2	30	23.0	1.8	102.0	7.0	6.0	8.1	6.4	1.8
		120	11.0	0.3	24.0	2.0	1.0	2.1	3.1	1.7
	3	30	17.0		86.0	2.0	7.0	8.3	3.0	1.6
		120	4.0		18.0	1.0	3.0	1.7	0.9	0.2

Note. For replications of prefeeding tests, the mean response rates are given.